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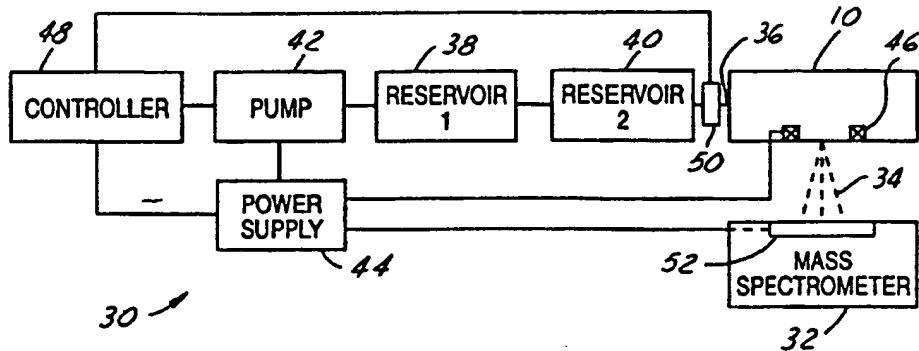
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(54) Title: LIQUID TRANSPORTATION SYSTEM FOR MICROFLUIDIC DEVICE



(57) Abstract

A method and apparatus for fluid transportation includes at least one fluid reservoir (38, 40) and a pump (42) that supplies the fluid to a microfluidic device (10) to form a droplet at an opening of the device (10). An electrode (46) located proximate the opening is supplied with power from power supply (44) to dispense the fluid in the form of a Taylor cone (34) or stream of droplets.

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**LIQUID TRANSPORTATION SYSTEM FOR MICROFLUIDIC DEVICE****Technical Field**

The present invention relates to microfluidic devices, and more particularly, to a 5 method and apparatus for distributing fluid within or from a microfluidic device.

**Background Of The Invention**

Methods of making a homologous series of 10 compounds, or the testing of new potential drug compounds comprising a series of light compounds, has been a slow process because each member of a series or each potential drug must be made individually and tested individually. For example, a plurality of 15 potential drug compounds that differ perhaps only by a single amino acid or nucleotide base, or a different sequence of amino acids or nucleotides are tested by an agent to determine their potential for being suitable drug candidates.

20 The processes described above have been improved by microfluidic chips which are able to separate materials in microchannels and move them through the microchannels. Moving the materials through microchannels is possible by use of various 25 electro-kinetic processes such as electrophoresis or electro-osmosis. Fluids may be propelled through

various small channels by the electro-osmotic forces. An electro-osmotic force is built up in the channel via surface charge buildup by means of an external voltage that can repel fluid and cause flow.

5 Other methods for moving materials through microchannels include, for example, pressure pumping. For this process, pressure heads are attached to the microfluidic chips and small bursts of pressured air or other gas, such as an inert gas, is directed into  
10 the microchannels.

Ultimately, the small volumes of liquids formed in the wells or reservoirs of a microfluidic device must be sampled and tested. Previous known methods for distributing and transporting fluids from  
15 the microfluidic devices include pressurizing the fluid to allow the fluid or a portion thereof to exit its chamber. One drawback to pressure pumping is that several parameters must be precisely controlled to expel a desired liquid amount. Such parameters  
20 include duration, the pulse magnitude, the channel dimension and solution viscosity.

#### Summary Of The Invention

It is, therefore, one object of the invention to provide an improved fluid dispensing system to dispense fluid from reaction wells. It is  
25 a further object of the invention to provide a controllable spray or stream of fluid for analysis.

It is yet another object of the present invention to provide a liquid handling drug discovery and diagnostic tool which increases the speed and productivity of discovering new drug candidates and 5 does so on a miniaturized scale or platform that reduces cost and manual handling. It is still a further object of the present invention to provide a multiple fluid sample processor, system and method which is capable of conveying, transporting, and/or 10 processing samples in a large multiplicity of sites.

In one aspect of the invention, a microfluidic fluid transportation system is coupled to a fluid pressure source. A microfluidic device has a fluid input coupled to the fluid pressure 15 source, and a channel having an opening therein. The fluid pressure source pumps fluid into the channel to form a droplet at the opening having a predetermined volume. An electrical contact is proximate the opening and a power source is coupled to the contact. 20 The power source selectively applies electrical power to the contact upon the formation of the droplet of a predetermined volume to form a fluid delivery.

In a further aspect of the invention, an inventive method is utilized which comprises forming 25 a droplet having a predetermined volume of fluid at an outlet, generating a potential difference between the fluid and a target, releasing the fluid, and, directing the fluid at the target.

One advantage of the invention is that small and controlled amounts of fluid may be delivered or transported without the need to control many parameters. Another advantage of the invention 5 is that the method for delivering fluid to microfluidic structures is applicable to structures having high integration densities and where viscous losses in micro channels are significant.

Other objects and features of the present 10 invention will become apparent when viewed in light of the detailed description of the preferred embodiment when taken in conjunction with the attached drawings and appended claims.

#### **Brief Description of the Drawings**

15 FIGURE 1 illustrates a multiple fluid sample processor according to the present invention;

FIGURE 2 is an exploded view of the processor shown in Figure 1;

20 FIGURE 3 is a block diagram schematic view of a microfluidic fluid transportation system according to the present invention.

FIGURE 4 is cross-sectional view of a well configured to transport liquid according to the present invention.

25 FIGURE 5 is a top view of Figure 4.

FIGURE 6 is a cross-sectional view of an alternative embodiment of a fluid transportation

system having contacts in a different position and including a nozzle.

FIGURE 7 is a cross-sectional view of a microfluidic device containing a fluid transportation system for moving fluid within a microfluidic device.

FIGURE 8 is a side view of a droplet formation formed according to the process of the present invention.

FIGURE 9 is a side view of a spray from an opening in a microfluidic device according to the present invention.

FIGURE 10 is an alternative stream of fluid from a microfluidic device.

FIGURE 11 is a cross-sectional view of a microfluidic device used for mixing two fluids.

FIGURE 12 is a cross-sectional view of a microfluidic device with respect to a receiving plate.

FIGURE 13 is a cross-sectional view of a microfluidic device having multiple openings.

#### **Detailed Description of the Preferred Embodiment**

Referring now to the drawings, like reference numerals are used to identify identical components in the various views. As illustrated below the present invention is particularly suited for use in connection with a microfluidic device. One skilled in the art, however, would recognize that the teachings of the present invention may be well

suited for use in a variety of industries such as genomics, surface coating, apportionment, proteomics and inkjet applications.

The present invention can be used 5 particularly in the industrialization of drug discovery processes including synthesis analysis and screening. The present invention increases speed and productivity while providing researchers with expanded capabilities and assuring quality. The 10 invention provides substantial time and efficiency advantages over prior techniques. The invention provides miniaturized liquid handling systems which perform the biological, chemical and the analytical processes fundamental to life sciences, research and 15 development. The invention can be utilized to perform thousands of reactions simultaneously in an integrated format, which substantially reduces the time, effort and expense required while improving the quality of the test results.

20 The processor in accordance with the present invention generally incorporates a modular configuration with distinct layers or plates. The processor or microfluidic device 10, as shown in Figure 1, is capable of conducting parallel synthesis 25 of thousands of small molecule compounds through the precise delivery of reagents to discrete reaction sites. This helps create a significantly larger number and variety of small molecules more effectively and with fewer resources.

With the present invention, arrays of DNA can be synthesized and transported on demand. The processor can also be used for high volume of sample processing and testing, as well as the search for new 5 molecular targets and determining expression levels and response to known drugs. The processor can incorporate multiple assay formats, such as receptor binding, antibody-antigen interactions, DNA/RNA amplification and detection, as well as magnetic bead 10 base separations. The versatility of the processor and its architecture make it available for use with synthesis work stations, genomic support stations, and analytical preparation systems.

A basic multiple fluid sample processor or 15 microfluidic device 10 in accordance with the present invention is shown in Figures 1 and 2. The microfluidic device is illustrated as a three-layered structure in the embodiment illustrated. The microfluidic device 10 is also called a fluid assay 20 layered device (FALD), or a fluidic array.

The microfluidic device 10 includes a top layer 12, which is also called a reagent reservoir. The microfluidic device 10 also includes a middle layer or fluidic delivery layer 14, as well as a 25 bottom layer or well plate 16.

The top layer 12 is also called a feed-through plate and serves as a cover for the microfluidic device 10. Layer 12 contains a number of apertures 18 which are selectively positioned

immediately above apertures 20 in layer 14. Apertures 20 are connected by an elongated micro-channels 22 which in turn have a plurality of branches extending therefrom. As illustrated, layer 5 14 comprises one layer, however, one skilled in the art would recognize that layer 14 may comprise several layers.

Well plate 16 has a plurality of wells 24 which are used to hold the reagents and other 10 materials in order for them to react and synthesize.

The three layers 12, 14 and 16 are stacked together to form a modular configuration. They are also coupled together tightly to form a liquid-tight seal. If desired, the top layer 12 can be bounded or 15 fused to the center distribution plate 14 or layer. The bottom or well plate layer 16, however, is detachably coupled to layer 16.

The plates 12, 14 and 16 may be made from any desirable material, such as glass, fused silica, 20 quartz, or silicon wafer material. The reservoirs, micro-channels and reaction cells are controllably etched or otherwise formed onto the plates using traditional semi-conductor fabrication techniques with a suitable chemical etchant or laser drilling.

25 Top plate 12 contains apertures 18 positioned above the openings 20 located in central plate 14. Apertures 18 provide the necessary openings for loading module to fill the reservoirs with a plurality of agents or other materials.

As will be further described below, a pressure pumping mechanism, is preferably used to assist in loading and distributing the reagents and other materials within the layers.

5       A typical need is for one of the sample plates to have each sample conveyed, transported and/or processed while eventually being delivered into the well plate. During this time, the samples are typically exposed to the atmosphere and can  
10 oxidize, evaporate or cross-contaminate to an undesirable extent. With the present invention, however, the multi-layered sample microfluidic device  
10 with detachable well plates inhibits cross-contamination of the fluids used in the combinatorial  
15 process.

The detachable layers in accordance with the present invention are preferably of a common dimensionality for ease of being handled by robotic or other automation means. A common set of  
20 dimensions has been adopted by many manufacturers which match that of the 96-well plate known as a "micro titer" plate.

Preferably, the plates 12, 14 and 16 are connected to each other by an indexing means of  
25 detents, flanges or locating pins so they are closely aligned in the horizontal and vertical directions. While engaged in such manner, samples from one of the plates can be caused to be moved and transported to another plate. Means for transporting or moving the

samples from one of the plates to the other can be by pumping, draining, or capillary action. While the samples are engaged, and as a result of the transport of the samples from one layer to the other, the 5 samples may be processed, reacted, separated, or otherwise modified by chemical or physical means, and then finalized by optical, electrochemical, chemical, or other means.

Samples or fluids can be delivered to the 10 microfluidic device 10 by being contained in one of the members of physically engaging sample multi-well plates, such as a top layer 12, or other means of sample introduction can be utilized, such as through the edges of such layer.

15 Referring now to Figure 3, a block diagram of a fluid transportation system 30 formed according to the present invention is illustrated. Fluid transportation system 30 controls the amount of fluid distributed from or within microfluidic device 10. 20 Fluid transportation system 30 is illustrated adjacent to a mass spectrometer 32 that is used for analyzing the composition of a fluid delivery 34 from microfluidic device 10. Mass spectrometer 32 analyzes the composition of fluid delivery 34 in a 25 well-known manner.

Microfluidic device 10 has a fluid input 36 which is coupled to a first fluid reservoir 38. As will be further described below, a second fluid reservoir 40 may also be coupled in series with first

fluid reservoir 38. A pump 42 is used to move fluid from first reservoir 38 and second fluid reservoir 40 into fluid input 36.

A power supply 44 is electrically coupled 5 to buffer reservoir or pump 42 to an electrode 46 in microfluidic device 10 and mass spectrometer 32. A controller 48 is coupled to power supply 44 and may be coupled to pump 42. Controller 48 controls the coupling of power to electrode 46, pump 42, and mass 10 spectrometer 32. Controller 48 is preferably microprocessor based. Controller 48, however, in its simplest form may comprise a number of switches. In the microprocessor form, controller 48 may include an internal timer.

15 A flow meter 50 may be positioned between fluid reservoir 38 and fluid input 36. Flow meter 50 may provide feedback to controller 48 with regard to the amount of fluid transported to microfluidic device 10.

20 Other feedback means to controller 48 may, for example, be timing for pump 42. If pump flows at a certain rate when operated, the amount of fluid delivered to microfluidic device 10 may be determined by a timer. The timer may be incorporated within 25 pump 42 or within controller 48 as described above.

In operation, controller 48 controls pump 42 to supply a predetermined amount of fluid from reservoirs 38 and 40. As will be further described below, as a droplet of fluid forms at an opening of

microfluidic device 10, power supply 44 under the control of controller 48 applies power to contacts 46 and between a target 52. A voltage potential difference exists between contact 46 and target 52 so 5 that fluid delivery 34 is formed therebetween.

A first reservoir 38 and second reservoir 40 may be used to electrically isolate pump 42 from microfluidic device 10. In this manner, second reservoir 40 provides isolation. Second reservoir 40 10 may be eliminated if another manner for electrical isolation is employed. In the illustration of Figure 3, a single pump and a pair of series reservoirs 38, 40 are employed. However, it is likely that various numbers of pumps and reservoirs may be used to 15 provide various reagents to microfluidic device 10.

Referring now to Figures 4 and 5, a portion of a microfluidic device 10 is shown. The portion shown, may, for example, be a well plate 54 having a well 56. A well plate 54 is described in Figures 1 20 and 2 as bottom layer 16. Well 56 receives fluids from the other layers of microfluidic device 10. Each fluid within each of the wells 56 of the device 10 must be analyzed. For many applications, it is desirable, however, to analyze only a small portion 25 of the fluidic solution in well 56. A sample outlet 58 is provided from well 56 through well plate 54. An opening 60 is formed at sample outlet 60. Sample outlet also has an entrance 62 adjacent to well 56. To sample fluid from well 56, fluid moves through

entrance 62 through sample outlet 58 and through opening 60.

Sample outlet 58 acts as a capillary channel from well 56. A capillary barrier or "break" 5 64 is formed at opening 60 of sample outlet 58. Capillary break 64 is formed by the surface tension of the fluid in sample outlet 58 when opening to a larger volume. Without a sufficiently high pressure or some other action, fluid within well 56 does not 10 flow from sample outlet 58.

An electrode 66 is positioned within sample outlet 58. Electrode 66 is illustrated as a ring electrode positioned at opening 60. The shape of electrode 66, however, may vary depending on the 15 application. Electrode 66 in any form should be capable of inducing a charge on fluid at outlet 58.

Referring now to Figure 6, electrode 66' may be positioned at entrance 62 to sample outlet 58. It has been experimentally found that the position of 20 electrodes 66, 66' in sample outlet 58 has little affect on the operation of fluid transportation system 30. A nozzle 68 may also be used to extend sample outlet 58 at opening 60. As shown, nozzle 68 forms a slight mesa that extends from the bottom of 25 well plate 54. For most fluids, the formation of nozzle 68 has little affect on the operation of fluid transportation system 30.

Referring now to Figure 7, a three layer microfluidic device 10 is illustrated. Fluid

transportation system may be incorporated within a microfluidic device 10 for providing fluid to various locations within microfluidic device. If accurate pumps or feedback systems are used, the amounts of 5 fluid may be metered precisely. Microfluidic device may, for example, have a top layer 70, a middle layer 72, and a bottom layer 74. Of course, the device illustrated in Figure 7 is only a portion of a microfluidic device 10. Microfluidic device 10 may, 10 for example, have a number of layers incorporated therein. In the present example, a capillary channel 76 is formed between top layer 70 and middle layer 72. Capillary channel 76 is ultimately coupled to a fluid reservoir such as that described above with 15 respect to Figure 3. Capillary channel 76 may feed an intermediate well 78 within microfluidic device 10. Electrodes 80 may be incorporated into microfluidic device to control the operation of fluid delivery as will be further described below.

20 Referring now to Figures 8 and 9, a droplet 82 is formed at opening 60 of sample outlet 58. The volume of droplet 82 may be precisely controlled by pump 42 and controller 48 of Figure 3. Once a droplet 82 having a desired volume is formed, power 25 supply provides a potential difference between contact 66 and target 52. Depending on the viscosity of the fluid and other characteristics, when a sufficient potential difference is applied between contact 66 and target 52, droplet 82 is formed into

fluid delivery 34. The type of fluid delivery 34 may include a Taylor cone 84 as illustrated in Figure 9. A Taylor cone is formed by charged particles 86 of droplet 82.

5 Referring now to Figure 10, charged particles 86 may also form a stream between opening 60 and target 52. A stream is formed when a relatively medium voltage potential is applied between electrode 66 and target 52. The type of  
10 fluid delivery 34 obtained is dependent upon the voltage. For example, voltage in the range between 500 volts and 3 kilovolts may be used.

Referring now to Figure 11, an alternative microfluidic device 10' is illustrated having a first  
15 well 56' and a second well 56''. Each well has a sample outlet 58' and 58''. Wells 56', 56'' may be coupled to the same fluids. In the preferred embodiment, however, wells 56', 56'' are coupled to two different fluids. That is, wells 56', 56'' may  
20 be coupled to two separate fluid reservoir/pump combinations. As described above, electrodes 66' and 66'' are located within sample outlets 58', 58''. When a droplet is formed in openings 60' and 60'', and a voltage potential is applied between contact  
25 60', 60'' and target 52, the droplets form fluid deliveries 34', 34''. In this manner, a mixing region 90 is formed by the combination of the fluid deliveries 34', 34''. Target 52 may be incorporated within a receiver plate or within a mass

spectrometer. It is believed that mixing region 90 provides superior distribution of fluid deliveries 34', 34'' for use with a mass spectrometer.

Referring now to Figure 12, yet another 5 alternative microfluidic device 10'' is illustrated. Microfluidic device 10'' has a well 56''' having a capillary channel 92 extending therefrom. Capillary channel 92 has a sample outlet 58'''. Capillary channel 92 is also illustrative of the fact that well 10 56''' may be located a distance from an opening 60''' in sample outlet 58'''. A nozzle 68''' may also be incorporated near opening 60'''.

When dispensing liquid from microfluidic device 10'', a receiver plate 94 may be positioned 15 adjacent to microfluidic device 10''. Receiver plate 94 has a receiving well 96 that may be used to transport samples of the solution formed in well 56'''. Receiving well 96 may have an electrode 98 coupled thereto. Electrode 98 in combination with 20 electrode 66''' has an electrical potential difference. The potential difference allows fluid to be dispensed from sample outlet 58'''.

Referring now to Figure 13, a microfluidic device 10''' is illustrated similar to that of 25 microfluidic device 10'' except having a multiple number of wells 56A through 56E. Wells 56A through 56E may each have different solutions therein. Microfluidic device 10''' may be used for mixing or dispensing solutions from wells 56A through 56E.

In operation, when fluid is to be transferred within or from a microfluidic device, a droplet is formed at an opening. When a desired volume droplet is formed, a spray voltage is applied 5 to an electrode within the fluid outlet. The application of voltage causes the droplet to be drawn towards an oppositely charged or grounded target. The particles of fluid or charge particles are attracted to the oppositely charged target. Charge 10 particles may form a fluid delivery shaped as a Taylor cone or as a stream or as a number of droplets. Depending on the voltage, the characteristics of the fluid delivery may be changed.

One skilled in the art would recognize that 15 a relatively low voltage may be maintained and when a fluid delivery is desired, the voltage may be increased to the desired level to obtain the desired fluid delivery characteristic.

While particular embodiments of the 20 invention have been shown and described, numerous variations and alternate embodiments will occur to those skilled in the art. Accordingly, it is intended that the invention be limited only in terms of the appended claims.

**What Is Claimed Is:**

1               1. A microfluidic fluid transportation  
2 system coupled to a fluid pressure source comprising:  
3                a microfluidic device having a fluid input  
4 coupled to the fluid pressure source and a channel  
5 having an opening therein;  
6                said fluid pressure source pumping fluid  
7 into said channel to form a droplet at said opening  
8 having a predetermined volume;  
9                a contact proximate said opening; and  
10               a power source coupled to said contact,  
11 said power source selectively applying electrical  
12 power to said contact upon the formation of said  
13 droplet of a predetermined volume to form a fluid  
14 delivery.

1               2. A microfluidic fluid transportation  
2 system as recited in claim 1 wherein said fluid  
3 delivery is responsive to a magnitude of said  
4 electrical power.

1               3. A microfluidic fluid transportation  
2 system as recited in claim 1 wherein said fluid  
3 delivery comprises a Taylor cone of droplets in  
4 response to a relatively high magnitude of said  
5 electrical power.

1               4. A microfluidic fluid transportation  
2 system as recited in claim 1 wherein said fluid  
3 delivery comprises a stream of droplets in response

4 to a relatively low magnitude of said electrical  
5 power.

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2 5. A microfluidic fluid transportation  
3 system as recited in claim 1 further comprising a  
4 sample outlet, said opening coupled at an end of said  
5 sample outlet.

1 6. A microfluidic fluid transportation  
2 system as recited in claim 5 wherein said contact is  
3 coupled at said opening.

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2 7. A microfluidic fluid transportation  
3 system as recited in claim 5 wherein said contact is  
4 coupled at an entrance to said sample outlet.

1 8. A microfluidic fluid transportation  
2 system as recited in claim 7 wherein said contact is  
3 coupled between an entrance to said sample outlet and  
4 said opening.

1 9. A microfluidic fluid transportation  
2 system as recited in claim 1 wherein said  
3 microfluidic device further comprises a well, said  
4 well comprising said opening.

1 10. A microfluidic fluid transportation  
2 system as recited in claim 1 wherein said fluid  
3 delivery comprises a Taylor cone of droplets.

1               11. A microfluidic fluid transportation  
2 system as recited in claim 1 wherein said fluid  
3 delivery comprises a stream of droplets.

1               12. A microfluidic fluid transportation  
2 system as recited in claim 1 wherein said fluid  
3 delivery comprises a spray of droplets.

1               13. A microfluidic fluid transportation  
2 system comprising:

3               a fluid pressure source;  
4               a microfluidic device having a fluid input  
5 coupled to the fluid pressure source and a channel  
6 having an opening therein;

7               said fluid pressure source pumping fluid  
8 into said channel to form a droplet at said opening  
9 having a predetermined volume;

10               a contact proximate said opening;

11               a power source;

12               a controller source selectively applying  
13 electrical power to said contact upon the formation  
14 of said droplet of a predetermined volume to form a  
15 fluid delivery.

1               14. A microfluidic fluid transportation  
2 system as recited in claim 13 wherein said first  
3 fluid pressure source comprises a first fluid  
4 reservoir and a pump, said first fluid reservoir  
5 coupled to said fluid input.

1           15. A mixing apparatus comprising:  
2           a first fluid pressure source;  
3           a second fluid pressure source;  
4           a microfluidic device having a first fluid  
5    input coupled to fluid pressure source, a first  
6    channel having an first opening therein, said  
7    microfluidic device having a second fluid input  
8    coupled to said second fluid pressure source, a  
9    second channel having a second opening therein;  
10           said first fluid pressure source pumping  
11    fluid into said channel to form a first droplet at  
12    said first opening having a first predetermined  
13    volume;  
14           said second fluid pressure source pumping  
15    fluid into said second channel to form a second  
16    droplet at said second opening having a second  
17    predetermined volume;  
18           a first contact proximate said first  
19    opening;  
20           a second contact proximate said second  
21    opening; and  
22           a power source coupled to said first  
23    contact and said second contact, said power source  
24    selectively applying electrical power to said first  
25    contact and said second contact upon the formation of  
26    said first and second droplet to mix a respective  
27    first and second fluid delivery.

1                   16. A mixing apparatus as recited in claim  
2 15 wherein said power source is simultaneously  
3 coupled to electrical power.

1                   17. A mixing apparatus as recited in claim  
2 15 further comprising a receiving plate having a  
3 mixing reservoir, said first and second fluid  
4 delivery are directed to said mixing reservoir.

1                   18. A system for analyzing a fluid  
2 comprising:

3                   an analyzer;  
4                   a power source;  
5                   a device having a fluid input and an  
6 opening therein;  
7                   an electrode proximate said opening;  
8                   a pump coupled to said power source;  
9                   a first reservoir coupled to said pump and  
10 to said fluid input; and  
11                  a controller coupled to said pump, and said  
12 power source, said controller controlling an amount  
13 of fluid formed at said opening and the application  
14 of a potential difference from said power source.

1                   19. A system as recited in claim 18  
2 further comprising a second fluid reservoir coupled  
3 in series with said first fluid reservoir.

1                   20. A system as recited in claim 18  
2 wherein said device further comprising a second  
3 opening having a second contact proximate thereto.

1                   21. A system as recited in claim 18  
2 wherein said analyzer comprises a mass spectrometer.

1                   22. A system as recited in claim 18  
2 wherein said controller comprises a microprocessor.

1                   23. A system as recited in claim 18  
2 wherein said opening comprises a nozzle.

1                   24. A method of dispensing liquid from a  
2 microfluidic device comprising the steps of:  
3                   forming a droplet having a predetermined  
4 volume of fluid at an outlet;  
5                   generating a potential difference between  
6 the fluid and a target;  
7                   releasing the fluid in response to the step  
8 of generating a potential difference; and  
9                   directing the fluid at the target.

1

1                   25. A method as recited in claim 24  
2 wherein the step releasing the fluid comprises the  
3 step of releasing the fluid in a spray.

1                   26. A method as recited in claim 24  
2 wherein the step of releasing the fluid in a spray  
3 comprises the steps of releasing the fluid in a  
4 Taylor cone.

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1               27. A method as recited in claim 24  
2 wherein the step releasing the fluid comprises the  
3 step of releasing the fluid in a stream.

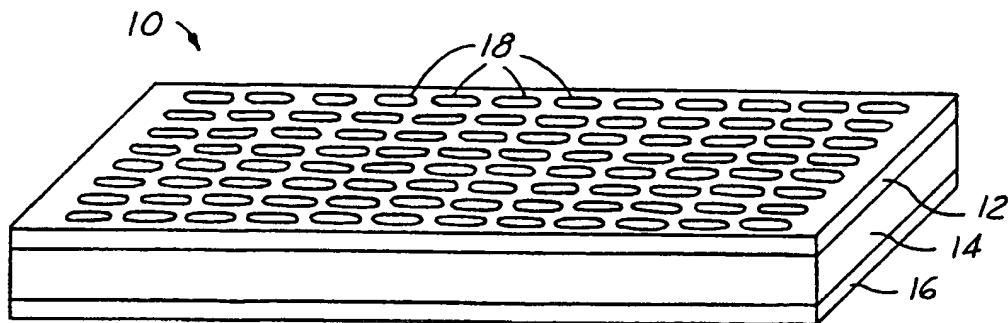


FIG. 1

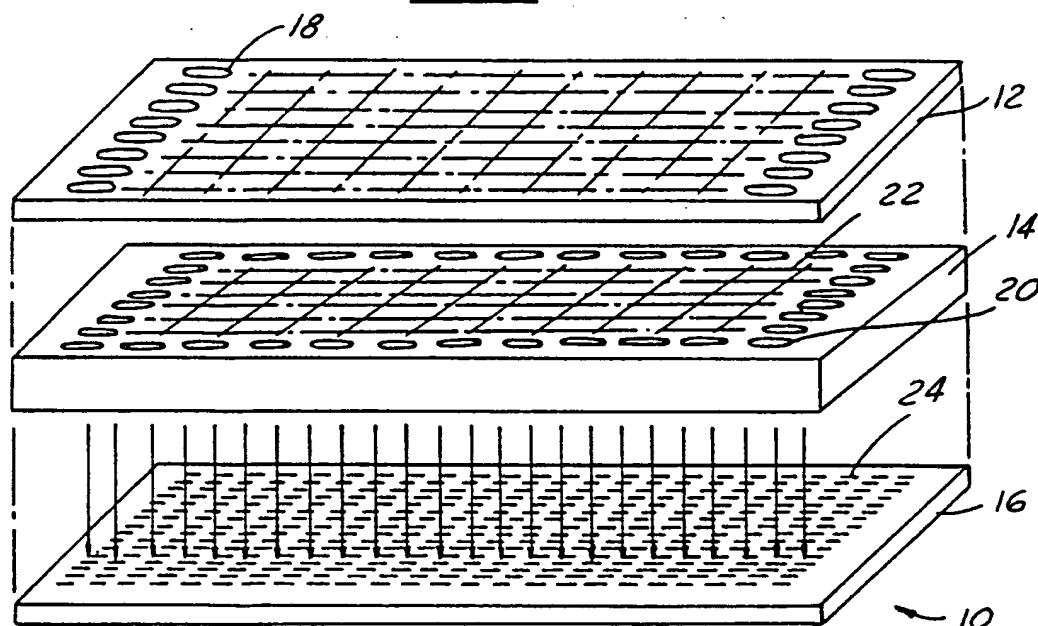


FIG. 2

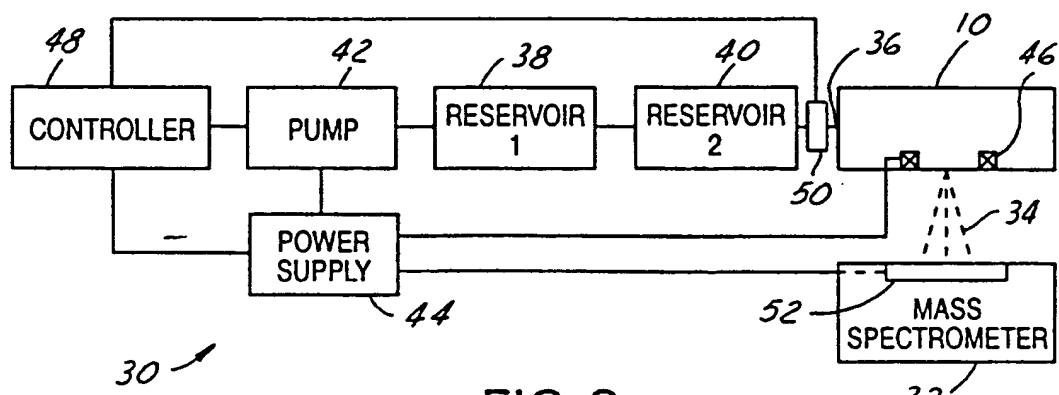
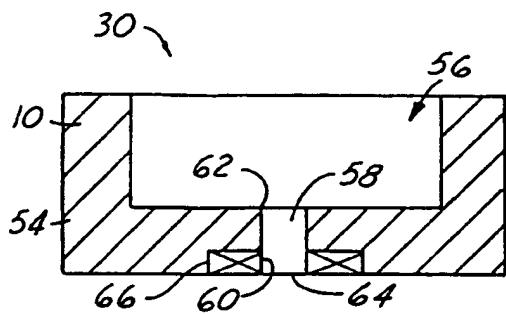
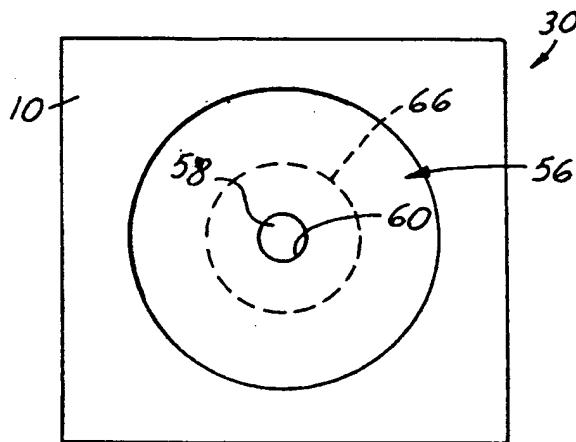
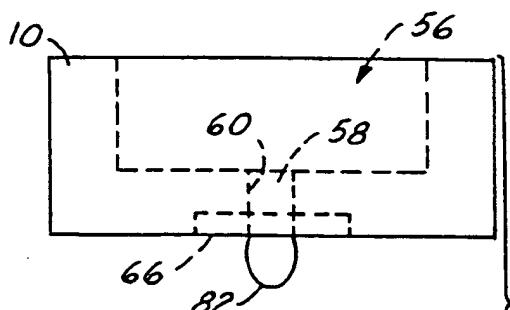
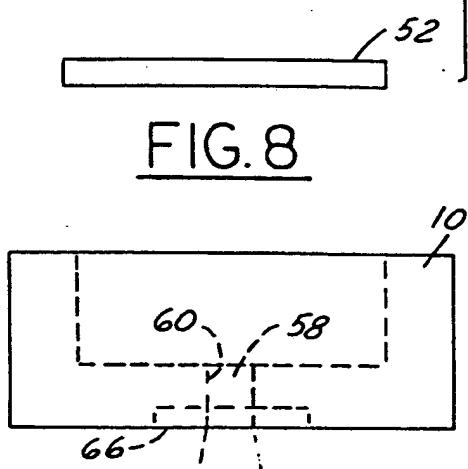
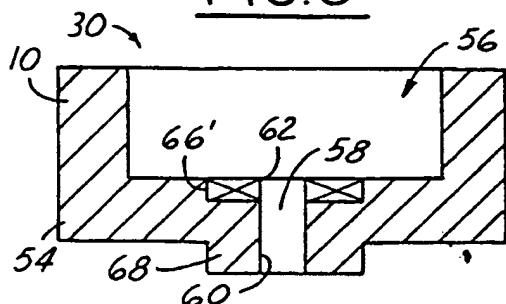
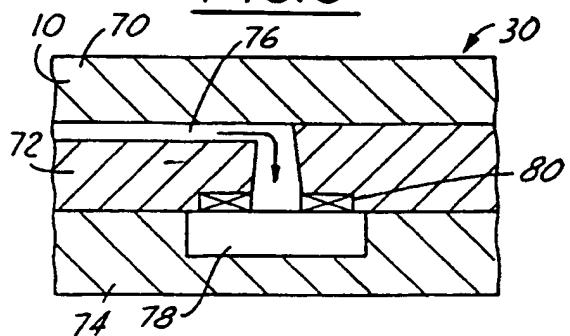
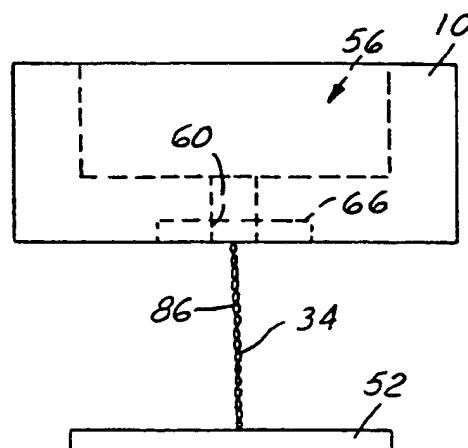


FIG. 3

FIG. 4FIG. 5FIG. 8FIG. 6FIG. 7FIG. 10

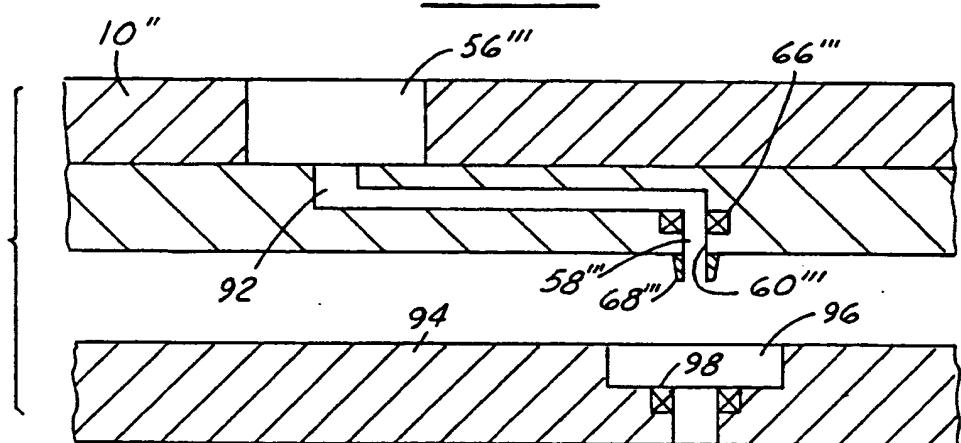
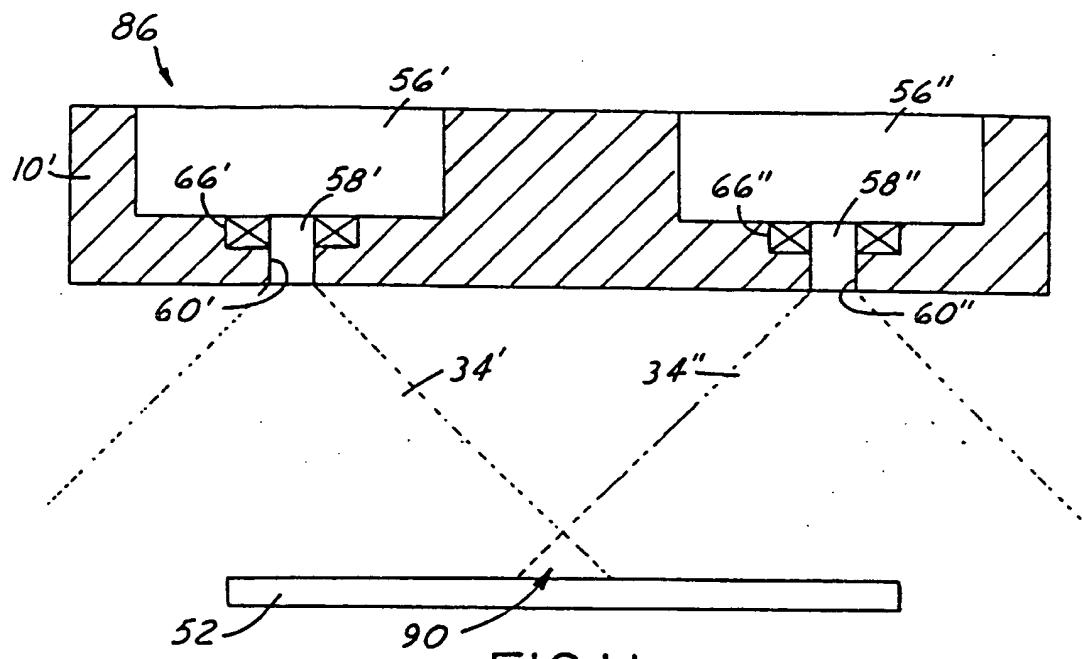
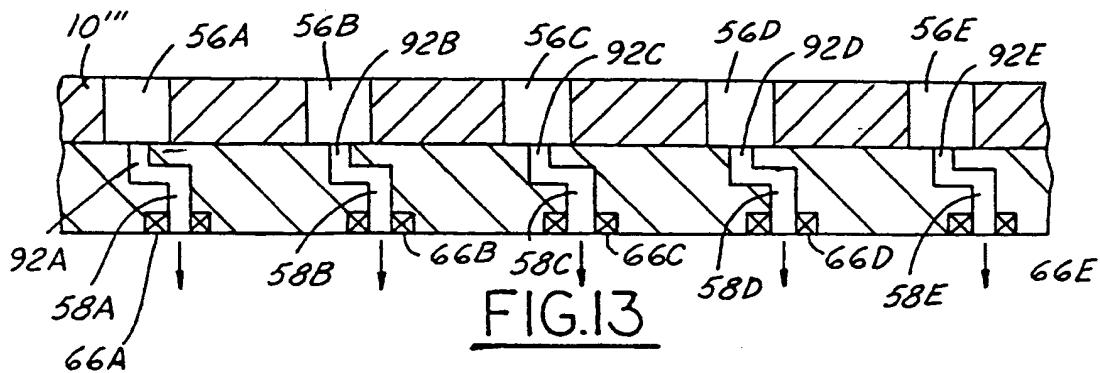


FIG. 12



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US00/10069

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :B01L 3/02

US CL :436/180; 422/100

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 436/180; 422/100

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,828,062 A (JARRELL et al) 27 October 1998 (27.10.98), see column 3, line 46 - column 4, line 51.	1-27

 Further documents are listed in the continuation of Box C.

See patent family annex.

•	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

28 JUNE 2000

Date of mailing of the international search report

13 JUL 2000

Name and mailing address of the ISA/US  
Commissioner of Patents and Trademarks  
Box PCT  
Washington, D.C. 20231

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**INTERNATIONAL SEARCH REPORT**

International application No.

PCT/US00/10069

**B. FIELDS SEARCHED**

Electronic data bases consulted (Name of data base and where practicable terms used):

EAST search terms: microfluidic\$ or microchannel\$ or micromachin\$ or micofabricat\$; 435/?..ccls. or 436/?..ccls. or 422/?..ccls.; electrode\$ or potential\$ or voltage\$ or charge\$; dispens\$ or drop\$ or fluid\$ or liquid\$; electrospray and mix\$